

[54] **CIRCULAR WAVEGUIDE MODE FILTER**  
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2,762,982 9/1956 Morgan, Jr..... 333/21 R  
 2,951,219 8/1960 Marcatili..... 333/21 R  
 3,321,720 5/1967 Shimada..... 333/21 R

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[21] Appl. No.: **272,037**

[57] **ABSTRACT**

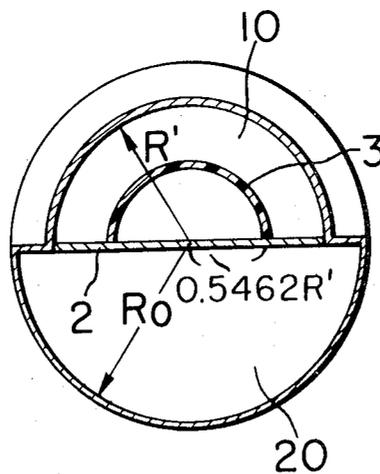
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 July 19, 1971 Japan..... 46-53688

A circular waveguide mode filter is provided which comprises a circular waveguide consisting of an upper and lower semicircular waveguide sections and in which dielectrics or magnetic materials are disposed in either of the upper or lower waveguide sections or in both of them in a special spatial relation with them so that the desired  $TE_{01}$  signal mode may be propagated through the waveguide while the undesired  $TE_{0n}$  (where  $n \geq 2$ ) modes are absorbed.

[52] U.S. Cl. .... 333/98 M, 333/21 R, 333/31 A  
 [51] Int. Cl. .... H01p 1/16, H01p 1/18  
 [58] Field of Search .... 333/98 M, 95 R, 21 R, 31 A

[56] **References Cited**  
 UNITED STATES PATENTS  
 2,129,669 9/1938 Bowen ..... 333/21 R

**10 Claims, 19 Drawing Figures**



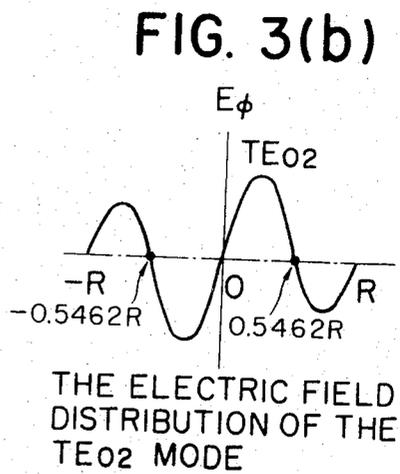
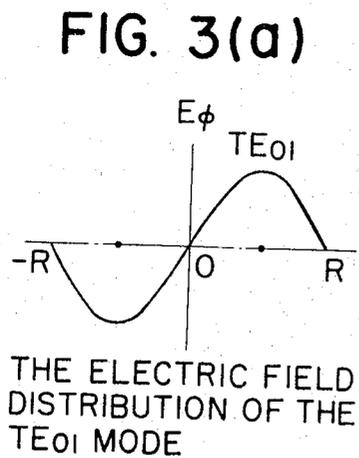
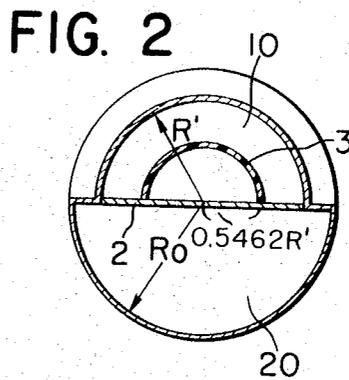
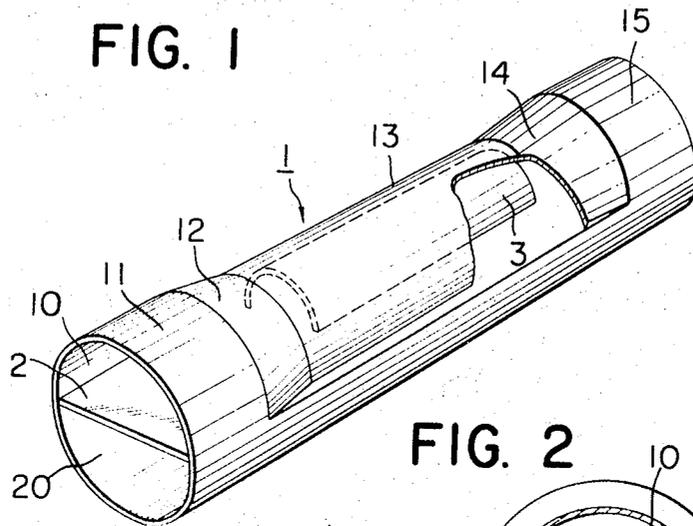
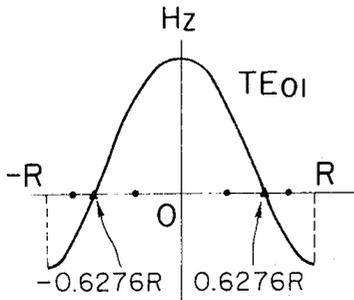
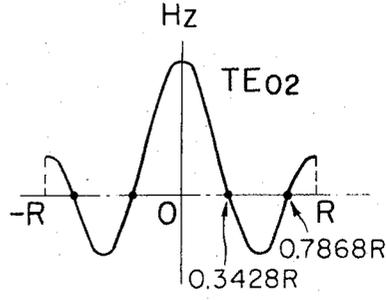


FIG. 3(c)



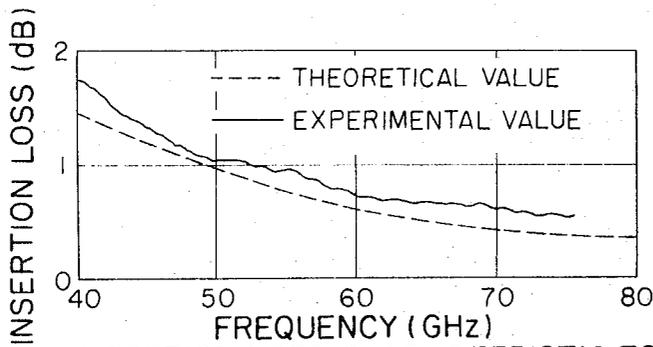
THE MAGNETIC FIELD DISTRIBUTION OF THE TE<sub>01</sub> MODE

FIG. 3(d)



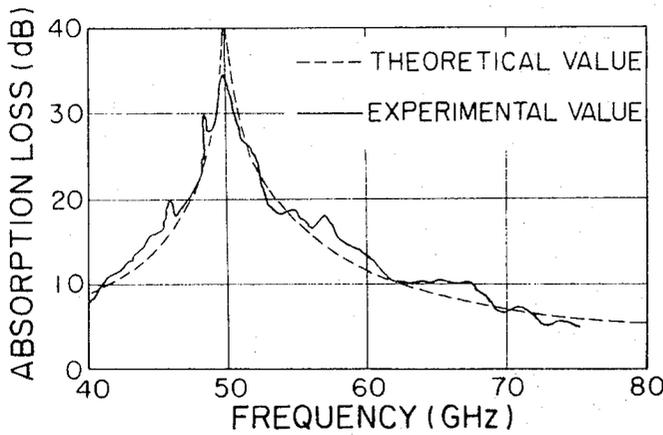
THE MAGNETIC FIELD DISTRIBUTION OF THE TE<sub>02</sub> MODE

FIG. 4(a)



INSERTION LOSS CHARACTERISTIC FOR TE<sub>01</sub> MODE (EXCLUDING DIELECTRIC)

FIG. 4(b)



ABSORPTION LOSS CHARACTERISTIC FOR TE<sub>02</sub> MODE (EXCLUDING DIELECTRIC)

FIG. 4(c)

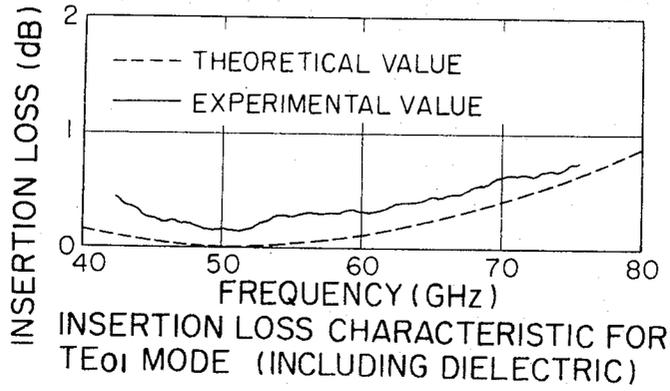


FIG. 4(d)

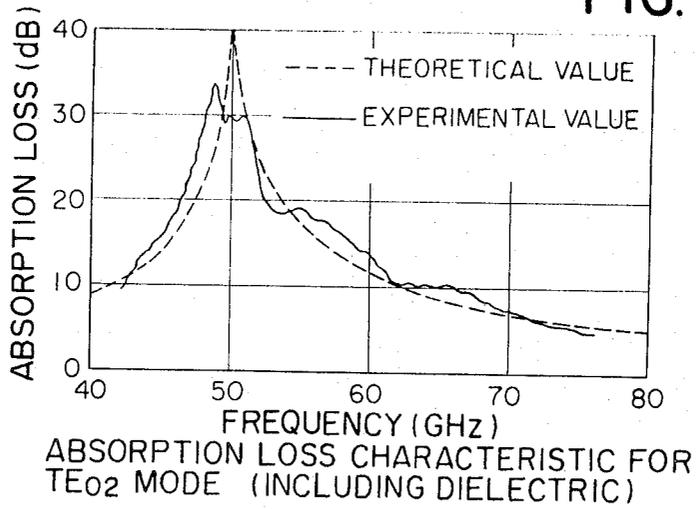


FIG. 6(a)

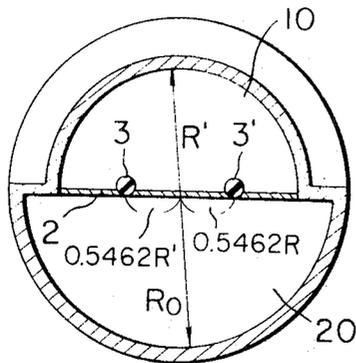


FIG. 6(b)

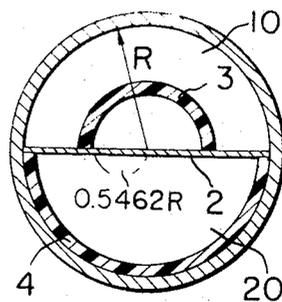
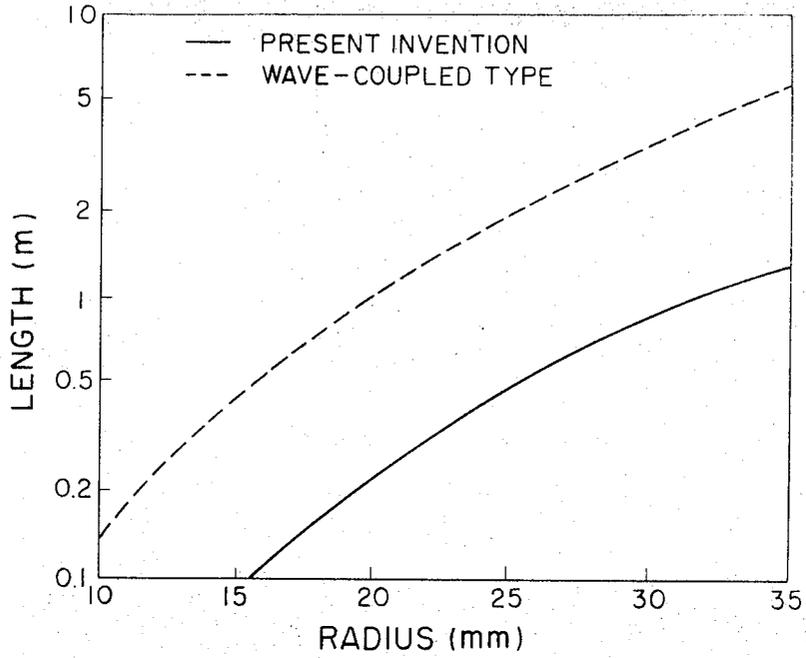
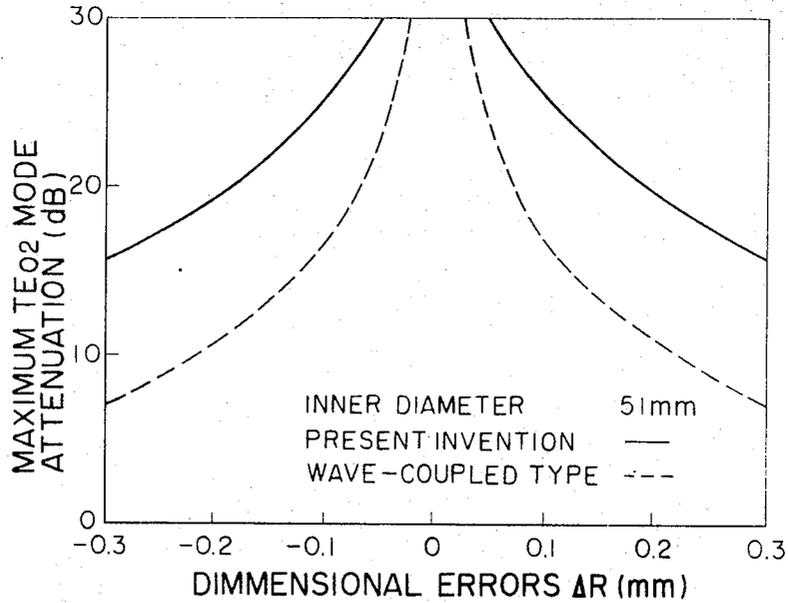


FIG. 5(a)



RELATION BETWEEN RADIUS R (mm) AND LENGTH (m) OF TE<sub>02</sub> MODE FILTERS

FIG. 5(b)



EFFECT UPON MAXIMUM ATTENUATION OF DIMENSIONAL ERRORS OF RADIUS OF WAVE GUIDE

FIG. 7(a)

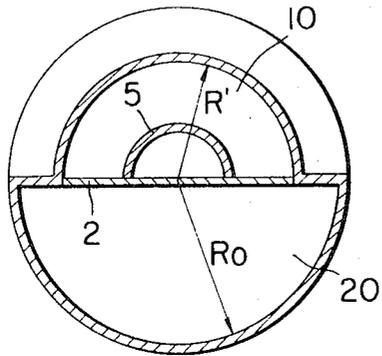


FIG. 7(b)

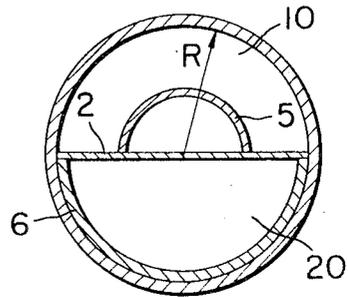


FIG. 8

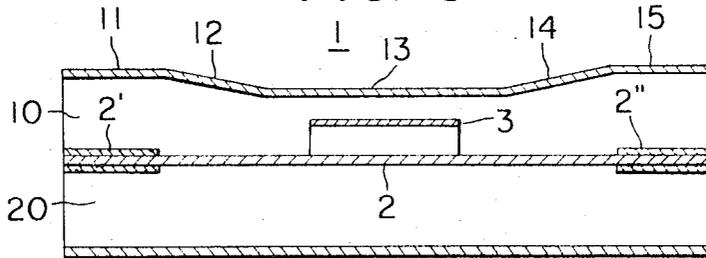


FIG. 9(a)

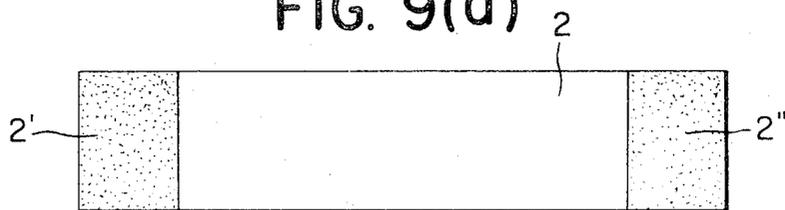
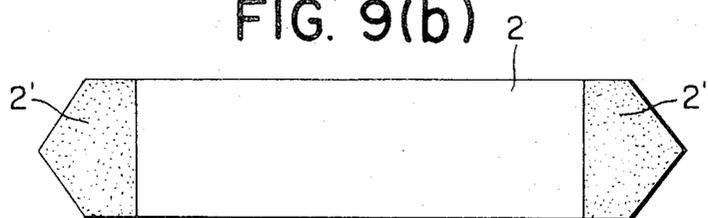


FIG. 9(b)



# CIRCULAR WAVEGUIDE MODE FILTER

## BACKGROUND OF THE INVENTION

The present invention relates to generally a filter used in TE<sub>01</sub> mode transmission lines composed of circular waveguides and more particularly a circular waveguide mode filter capable of giving high attenuation to the undesired higher modes such as the circular TE<sub>02</sub> mode without affecting the propagation of the desired circular TE<sub>01</sub> mode.

Circular waveguides used in the millimeter wave communication systems generally have an inner diameter considerably greater than the wavelength of the desired TE<sub>01</sub> mode in order to reduce the attenuation due to the wall heat loss of said mode. For example, the circular waveguide for a millimeter wave communication system whose frequency range is from 40 to 80 GHz or from 40 to 120 GHz has an inner diameter from 40 to 60 mm. Therefore, a considerable number of modes can be propagated through the circular waveguide. When the helix waveguides are used as the transmission lines, the undesired modes other than the circularly symmetric modes such as TE<sub>02</sub>, TE<sub>03</sub> and TE<sub>04</sub> may be sufficiently suppressed, so that the circular waveguide line must be generally provided with mode filters for attenuating the undesired TE<sub>0n</sub> modes ( $n \geq 2$ ). Furthermore, the undesired modes TE<sub>0n</sub> ( $n \geq 2$ ) are generated in the corner waveguides which may be regarded as a sort of mirror capable of bending the microwaves at sharp angles at bends. In inter-city or inter-office trunk lines which have a considerable number of bends, the corner waveguides are used so that the degradation of the transmission characteristic occurs due to the conversion and reconversion of the TE<sub>01</sub> signal mode and the undesired TE<sub>0n</sub> ( $n \geq 2$ ) modes. Therefore, mode filters must be provided capable of absorbing the undesired modes generated in the corner waveguides.

In general, of the undesired modes, the lowest mode, TE<sub>02</sub> mode is most dominant so that when the latter is sufficiently suppressed or absorbed, other undesired modes will not present a serious problem in the microwave transmission lines in practice. Therefore, the present invention is mainly directed to the absorption and attenuation of the TE<sub>02</sub> mode, but it should be understood that the present invention may be also applied to the absorption and attenuation of other undesired modes.

In order to absorb and attenuate the undesired TE<sub>02</sub> mode, there has been proposed a wave coupling type mode filter in which a large number of coupling holes are formed through the wall of an inner circular waveguide so that of the TE<sub>01</sub> and TE modes propagating through the inner waveguide, the undesired TE<sub>02</sub> mode may be directed into an outer circular waveguide through the coupling holes. When the wave coupling type mode filter of the type described above is inserted into the microwave transmission line in practice, tapered waveguides with a considerable length must be coupled to both ends of the wave coupling type mode filter so that various problems arise such as over-all length of the wave coupling type mode filter including the tapered waveguide couplings, of the confined resonance, the dimensional tolerances or errors caused in manufacturing and laying, and the like.

There has been proposed and demonstrated a resonant slot type mode filter of the type in which a lossy material having a large number of slots formed at a point where the field intensity of the TE<sub>01</sub> signal mode becomes zero is inserted in the waveguide so as to divide the waveguide into two sections. Therefore, when TE<sub>01</sub> and TE<sub>02</sub> modes propagate through the waveguide, the undesired TE<sub>02</sub> mode may be absorbed by the lossy material. However, the attenuation of the undesired TE<sub>02</sub> mode higher than 2 dB/m attained by the resonant slot type mode filter is in the relatively narrow frequency band of 5 GHz at 50 GHz. In other words, the resonant slot type mode filter is not adapted for use in the broad band. Furthermore, the higher the frequency, the lower becomes the attenuation of the undesired TE<sub>02</sub> mode.

Furthermore, there has been devised and demonstrated a circular waveguide mode filter of the type comprising a pair of upper and lower semicircular waveguide sections having different radii. The underlying principle of the circular waveguide mode filter is based on the fact that the phase velocities of the semicircular modes propagating through the semicircular waveguide sections having different radii are different from each other. Based upon this principle, the undesired TE<sub>02</sub> mode may be attenuated without the desired TE<sub>01</sub> mode being adversely affected. More particularly, for the desired semicircular TE<sub>01</sub> mode, the phase difference between the pair of semicircular waveguide sections is an integer integral of  $2\pi$ , (that is  $2n\pi$  where  $n = 0, 1, 2, 3, \dots$ ) so that the electric fields of the TE<sub>01</sub> modes may be directed in the same directions at the outlet of the each semicircular waveguide. As for the undesired TE<sub>02</sub> mode, the phase difference of the TE<sub>02</sub> modes propagating through the upper and lower waveguide sections is made an odd integer of  $\pi$ , (that is,  $(2n + 1)\pi$  where  $n = 0, 1, 2, 3, 4, \dots$ ) so that the electric fields at the outlet of the waveguide are directed in opposite directions. Therefore, the two semicircular TE<sub>01</sub> modes propagating through the upper and lower semicircular waveguides are composed into one circular TE<sub>01</sub> mode and are not affected at all, whereas the two semicircular TE<sub>02</sub> modes at the outlet of the waveguide are converted into the TM<sub>12</sub> mode and the like, which may be absorbed by the helix waveguide. However, in the circular waveguide mode filter of the type described, the specific phase relations described above are not maintained when the frequency varies so that the insertion loss of the TE<sub>01</sub> mode is increased. As a result, the prior art circular waveguide mode filter is not effective over a broad band. Furthermore, the attenuation of the undesired TE<sub>02</sub> mode is dependent solely upon the mode conversion at the output of the waveguide so that the multiple reflections in the semicircular waveguide sections occur. As a result, the TE mode absorption effect is reduced and the reflection characteristic of the desired TE<sub>01</sub> mode is adversely affected.

At the outlet of the waveguide, the mode conversion generates diverse modes some of which cannot be effectively absorbed by the helix waveguide. Therefore, the reconversion into the TE<sub>02</sub> mode will occur at the imperfect portions of the helix waveguide.

One of the objects of the present invention is therefore to provide an improved circular waveguide mode filter with a broad band width.

Another object of the present invention is to provide an improved circular waveguide mode filter which is shorter in over-all length, simple in construction and reliable and dependable in operation and not so severe in manufacturing and laying tolerances or errors as compared with the prior art mode filters.

According to one aspect of the present invention, a circular waveguide mode filter comprises a pair of semi-circular waveguide sections having different radii, and a dielectric disposed in the semicircular waveguide section having a smaller radius at such a position where said dielectric will not adversely affect the  $TE_{02}$  mode propagating through said semicircular waveguide section with a smaller radius. The phase velocity of the  $TE_{02}$  mode propagating through the semicircular waveguide section with a smaller radius becomes different from that of the  $TE_{02}$  mode propagating through the other semicircular waveguide section with a greater radius so that the field intensity of the  $TE_{02}$  mode propagating through the semicircular waveguide section with a smaller radius is directed at the outlet of the mode filter in the direction opposite to that of the field intensity of the  $TE_{02}$  mode propagating through the other semicircular waveguide section with a greater radius. As for the desired  $TE_{01}$  mode, the apparatus radius of the semicircular waveguide section with a smaller radius becomes equal to that of the other semicircular waveguide section with a greater radius because of the dielectric or magnetic material disposed in the semicircular waveguide section with a small diameter so that the  $TE_{01}$  modes propagating through the both waveguide sections become equal in phase velocity. Thus only the circular  $TE_{01}$  mode is derived from the outlet of the circular waveguide mode filter whereas the undesired circular  $TE_{02}$  mode is absorbed by the mode filter.

The above and other objects, features and advantages of the present invention will become more apparent from the following description of the preferred embodiments thereof taken in conjunction with the accompanying drawing.

#### BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a perspective view partly in section of a circular waveguide mode filter in accordance with the present invention;

FIG. 2 is a cross sectional view thereof;

FIGS. 3a through 3d illustrate the electric and magnetic field distributions of the circular  $TE_{01}$  and  $TE_{02}$  modes used for explanation of the underlying principle of the present invention;

FIGS. 4(a) and 4(b) are curves illustrating the insertion loss of the  $TE_{01}$  mode and attenuation loss of the  $TE_{02}$  mode respectively of a circular waveguide without the dielectric of FIG. 1;

FIGS. 4(c) and 4(d) are curves corresponding to FIGS. 4(a) and 4(b) respectively when a dielectric is employed, as shown in FIG. 1.

FIGS. 5a and 5b illustrate the advantages of the circular waveguide mode filter in accordance with the present invention over the prior art wave coupling type mode filter;

FIGS. 6(a) and 6(b) are cross sectional views of a second and a third embodiments of the present invention of the type utilizing the dielectric materials;

FIGS. 7(a) and 7(b) are cross sectional views of a fourth and fifth embodiments of the present invention of the type utilizing the magnetic materials;

FIG. 8 is a longitudinal sectional view of a modification of the embodiment shown in FIG. 1; and

FIGS. 9(a) and 9(b) are top views of modifications of a thin metallic slab or sheet partition wall having resistor elements or films.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, a circular waveguide mode filter generally designated by 1 in accordance with the present invention generally comprises an upper and lower semicircular waveguide sections 10 and 20 partitioned from each other by a thin metallic slab 2. The middle waveguide section 13 of the upper semicircular waveguide section 10 has a radius smaller than that of the lower semicircular waveguide section 20, and a semi-cylindrical dielectric 3 having a radius smaller than that of the middle waveguide section 13 is disposed inside the section 13 coaxially thereof. More particularly, as shown in FIG. 2, the radius  $R_0$  of the lower waveguide section 20 is greater than the radius  $R'$  of the middle waveguide section 13, and the semi-cylindrical dielectric 3 has a radius equal to  $0.5462R'$ . The middle waveguide section 13 has both of its ends joined to the semicircular waveguide sections 11 and 15 on the sides of the input and output respectively, through tapered semicircular waveguide sections 12 and 14, respectively.

In a semicircular or circular waveguide, the radial field distributions of the transverse electric field components  $E_\phi$  and the longitudinal magnetic field components  $H_z$  of the  $TE_{01}$  and  $TE_{02}$  modes are shown in FIG. 3. That is, the electric field distributions of the  $TE_{01}$  and  $TE_{02}$  modes are shown in FIGS. 3(a) and 3(b), respectively, whereas the magnetic field distributions are shown in FIGS. 3(c) and 3(d), respectively. For example, in FIG. 3(b), the electric field component  $E_\phi$  of the  $TE_{02}$  mode becomes zero at a point spaced apart by  $0.5462R$  from the center. Therefore when the dielectric 3 is disposed as shown in FIG. 2 at a distance of  $0.5462R'$  from the center of the upper semicircular waveguide section 10, the  $TE_{02}$  semicircular waveguide propagating through the section 10 is not substantially affected by the dielectric 3 except that its phase velocity is changed because the radius of the middle waveguide section 13 is smaller. As for the  $TE_{01}$  mode propagating through the semicircular waveguide section 10, the apparent radius of the section 10 becomes greater because of the influence from the dielectric 3. The phase velocities of  $TE_{02}$  modes propagating through the semicircular waveguide sections 10 and 20 are different from each other because of the difference in radius of the upper and lower semicircular waveguide sections 10 and 20. Therefore, it becomes possible to reverse the directions of the  $TE_{02}$  modes propagating through the waveguide sections 10 and 20 at the outlets thereof if the lengths thereof are suitably selected. Furthermore, for the  $TE_{01}$  modes the apparent radius of the upper semicircular waveguide 10 may become equal to the radius of the lower semicircular waveguide section 20 when the radii of the upper and lower semicircular waveguide sections 10 and 20 and the dielectric material 3 are suitably selected. As a result, there will be difference in phase velocity between the  $TE_{01}$  modes propagating through the upper and lower semicircular waveguide sections 10 and 20. That is, the directions of the electric fields of the  $TE_{01}$  modes at the outlets of the

semicircular waveguide sections 10 and 20 become equal. In this case, the  $TE_{01}$  modes propagating through the upper and lower semicircular waveguide sections 10 and 20 have no phase difference.

In the experiments conducted by the inventor, the circular waveguide shown in FIG. 1 comprising the input and output waveguide sections 11 and 15, 100 mm in length, the tapered waveguide sections 12 and 14, 75 mm in length and the middle section 13, 300 mm in length and having the overall length of 650 mm was used. The radius  $R'$  of the upper semicircular waveguide section 10 was 23.0 mm whereas the radius  $R_0$  of the lower semicircular waveguide section 20 was 25.5 mm. The semi-cylindrical dielectric 13 with a dielectric constant of 1.03 and a length of 100 mm and a thickness of 2.0 mm was disposed in the semicircular waveguide section 10 at a distance of  $0.5462R'$  from the center thereof.

The experimental results are shown in FIG. 4. FIGS. 4(a) and 4(b) show the insertion loss characteristic of the  $TE_{01}$  mode and attenuation loss characteristic of the  $TE_{02}$  mode when the dielectric 3 was not used. As seen from FIG. 4(a), when the dielectric 3 is not used, the loss of the  $TE_{01}$  mode signal is relatively higher, about 2 dB at a low frequency, and therefore is not satisfactory in practice. However the better  $TE_{02}$  mode characteristic corresponding to the theoretical value may be obtained. FIGS. 4(c) and 4(d) show the corresponding characteristics when the dielectric 3 was inserted. In FIG. 4, the experimental values are indicated by the solid lines whereas the theoretical values, by the broken lines. From FIG. 4, it is readily seen that the improvement over the loss characteristic of the  $TE_{01}$  mode can be attained by the insertion of the dielectric 3 into the semicircular waveguide section 10 with the smaller radius of the circular waveguide 1. The reason is that, as described above, the apparent radius of the upper semicircular waveguide section 10 for the  $TE_{01}$  mode becomes equal to the radius of the lower semicircular waveguide section 20. The effect of the dielectric 3 upon the  $TE_{02}$  mode is almost negligible, and the absorption loss becomes greater because of the difference in radius between the upper and lower semicircular waveguide sections 10 and 2.

The advantages of the mode filter in accordance with the present invention over the prior art wave-coupled type mode filter are best shown in FIG. 5. FIG. 5(a) shows the relation between the radius and length of the filter; and FIG. 5(b), the relation between the dimensional error in radius of the filter and the maximum attenuation of the  $TE_{02}$  mode. In FIG. 5, the mode filter in accordance with the present invention is designated by the solid lines, where as the prior art mode filter, by the broken lines. It is readily seen that the overall length of the mode filter in accordance with the present invention is shorter than that of the prior art mode filter and that the dimensional errors or tolerances required for the mode filter in accordance with the present invention are not so severe as those required for the prior art mode filter.

In addition to the mode filter for the circular waveguide described so far with reference to FIGS. 1 and 2, various modifications and variations can be effected.

In the second embodiment of the present invention shown in FIG. 6(a), the circular waveguide comprises the upper and lower semicircular waveguide sections 10 and 20 partitioned from each other by the metallic

slab or sheet 2 as in the case of the first embodiment, but instead of the semi-cylindrical dielectric 3, dielectric rods 3 and 3' are disposed in the upper semicircular waveguide section 10 with a smaller radius at a distance equal  $0.5462R'$  respectively on both sides of the center of the section 10. The mode of operation of the second embodiment is substantially similar to that of the first embodiment. That is, the effects of the dielectric rods 3 and 3' upon the  $TE_{02}$  mode propagating through the semicircular waveguide section 10 are almost negligible, but the phase velocity is changed as the radius of the upper semicircular waveguide section 10 is smaller. As for the  $TE_{01}$  mode, the apparent radius of the upper semicircular waveguide section 10 becomes greater because of the presence of the dielectric rods 3 and 3' so that the phase velocity of the  $TE_{01}$  mode propagating through the upper semicircular waveguide section 10 equals that of the  $TE_{01}$  mode propagating through the lower semicircular waveguide section 20.

In the third embodiment shown in FIG. 6(b), the upper and lower semicircular waveguide sections 10 and 20 have the same radius, and semicircular dielectric 3 is disposed within the upper semicircular waveguide section 10 at a distance equal to  $0.5462R$  from the center thereof as in the case of the first embodiment, whereas a semi-cylindrical dielectric 4 is disposed upon the inner wall of the lower semicircular waveguide section 20. That is, the apparent radius for the  $TE_{02}$  mode of the lower semicircular waveguide section 20 which has the same radius with that of the upper semicircular waveguide section 10 is made greater by disposing the semi-cylindrical dielectric 4 within the lower section 20 so that the phase velocities of the  $TE_{02}$  modes propagating through the waveguide sections 10 and 20 may be different from each other. As for the  $TE_{01}$  mode propagating through the lower semicircular waveguide section 20, the apparent radius becomes greater, but the apparent radius for the  $TE_{01}$  mode propagating through the upper semicircular waveguide section 10 becomes greater because of the presence of the dielectric 3. As a consequence, there is no difference in phase velocity between the  $TE_{01}$  modes propagating through the upper and lower semicircular waveguide sections 10 and 20.

As is clear from FIGS. 3(c) and 3(d), the same effects can be attained when the magnetic materials are used instead of the dielectric materials.

The fourth and fifth embodiments of the present invention employing magnetic material are shown in FIG. 7. The fourth embodiment shown in FIG. 7(a) is substantially similar in construction to the first embodiment described with reference to FIGS. 1 and 2 except that a semi-cylindrical magnetic material 5 is disposed within the upper semicircular waveguide section 10 with a radius smaller than that of the lower semicircular waveguide section 20, at a distance equal to  $0.3428R'$  from the center of the upper waveguide section 10.

The fifth embodiment shown in FIG. 7(b), is substantially similar in construction to the third embodiment described with reference to FIG. 6(b) except that a semi-cylindrical magnetic material 5 is disposed within the upper semicircular waveguide section 10 at a predetermined distance from the center thereof and the magnetic material 6 is disposed to contact the inner wall of the lower semicircular waveguide section 20 having the radius equal to that of the upper waveguide section 10.

The mode of operation of the fourth and fifth embodiments described above with reference to FIGS. 7(a) and 7(b) is substantially similar to that of the first and third embodiments described with reference to FIGS. 1 and 2 and FIG. 6(b), respectively.

The mode filter for the circular waveguide in accordance with the present invention described so far has various advantages hitherto unattained by the prior art mode filters, but the problem of the reflected waves in the filter is left unsolved. However, the present invention can also solve this problem as will become more apparent from the following embodiments to be described in conjunction with FIGS. 8 and 9.

FIG. 8 is a longitudinal sectional view of the waveguide shown in FIG. 1. The circular waveguide generally designated by 1 is divided into the upper and lower semicircular waveguide sections 10 and 20 by the metallic slab 2, and the semi-cylindrical dielectric 3 is disposed within the middle section 13 with a radius smaller than the upper waveguide section 11 or 15. When the effect of the reflected waves traveling back and forth in the waveguide 1 is not negligible, resistor elements or films 2' and 2'' are disposed upon the partition wall 2 in the inlet and outlet waveguide sections 11 and 15 in opposed relation with the inner walls thereof. The  $TE_{02}$  modes, which propagate through the upper and lower semicircular waveguide sections 10 and 20 and which are out of phase at the outlets of the waveguide sections 10 and 20, may be absorbed by the resistor element or film 2'' so that the problem of the reflected waves may be overcome. The resistor film 2' at the inlet can absorb the still remaining reflected waves of the  $TE_{01}$  and  $TE_{02}$  modes which are out of phase in the upper and lower semicircular waveguide sections 10 and 20. Thus, multireflection can be prevented. The resistor elements 2' and 2'' are disposed at right angles to the directions of the electric field intensities of the  $TE_{01}$  modes which are in phase in the upper and lower semicircular waveguide sections 10 and 20 so that they are almost not affected when the thickness of the resistor films or elements 2' and 2'' is made sufficiently smaller relative to the wavelength. Although the two resistor films or elements 2' and 2'' have been described as being disposed at the inlet and outlet of the waveguide respectively, it is sufficient in practice to place only the resistor element or film 2'' at the outlet of the waveguide. In FIG. 8 the upper and lower semicircular  $TE_{0n}$  modes opposite in phase are subjected to asymmetrical mode transformation at the output section of the metallic partition plate. Since all of the electric fields of these modes have a component in parallel with the metallic plate, the current becomes in parallel with the thin resistance films when the latter are disposed in parallel with the metallic partition plate as shown in FIG. 8 so that the asymmetrical modes, which have been transformed in mode, may be absorbed over an extremely short distance. Whereas a few meters of a helix waveguide is required to absorb the asymmetrical modes, according to the present invention only 1 percent of the length of the helical waveguide is required.

FIG. 9(a) shows a rectangular thin metallic slab 2 having the rectangular resistor plates or films 2' and 2''. FIG. 9(b) shows the modification of the thin metallic partition slab 2 having the tapered or pentagonal resistor films or elements 2' and 2'' which are more effective

in absorbing the reflected waves than the rectangular resistor elements shown in FIG. 9(a).

In addition to the variations and modifications described so far, further variations and modifications occur to those skilled in the art without departing from the scope of the present invention. For example, for input and output waveguide sections 11 and 15, helical waveguides or ring mode filters may be utilized in order to absorb the undesired modes generated by the imperfections of the waveguides. Furthermore, instead of the semicircular waveguide sections, helix waveguides may be utilized.

So far only the absorption of only the  $TE_{02}$  mode has been taken into consideration, but the waveguide in accordance with the present invention may be so designed as to absorb other higher circular modes. In this case, it is of course necessary to change the positions of the dielectric or magnetic materials inserted into the waveguide because the electric and magnetic field distributions of the higher modes are different from those of the  $TE_{02}$  mode.

What is claimed is:

1. A circular waveguide mode filter of the type with low transmission losses for the desired  $TE_{01}$  mode and with high attenuation for the undesired  $TE_{0n}$  modes (where  $n \geq 2$ ) comprising
  - a circular waveguide comprising a pair of semicircular waveguide sections having different radii, and a dielectric so disposed in one of said pair of semicircular waveguide sections with a smaller radius that the propagation of said undesired  $TE_{0n}$  modes may not be adversely affected by said dielectric.
2. A circular waveguide mode filter as set forth in claim 1 wherein
  - said dielectric is disposed at a position spaced apart from the center of said one semicircular waveguide section with a smaller radius by a distance equal to  $0.5462R$  where  $R$  = the radius of said one semicircular waveguide section.
3. A circular waveguide mode filter as set forth in claim 2, comprising a thin metallic slab positioned to partition said pair of circular waveguide sections, and a resistive material in contact with said thin metallic slab.
4. A circular waveguide mode filter as set forth in claim 1 wherein
  - said dielectric is replaced by a magnetic material in said one semicircular waveguide section with a smaller radius.
5. A circular waveguide mode filter as set forth in claim 4, comprising a thin metallic slab positioned to partition said pair of circular waveguide sections, and a resistive material in contact with said thin metallic slab.
6. A circular waveguide mode filter as set forth in claim 4, comprising a thin metallic slab positioned to partition said pair of circular waveguide sections, and a resistive material in contact with said thin metallic slab.
7. A circular waveguide mode filter as set forth in claim 1, comprising a thin metallic slab positioned to partition said pair of circular waveguide sections, and a resistive material in contact with said thin metallic slab.
8. A circular waveguide mode filter of the type with low transmission losses for the desired  $TE_{01}$  mode and with high attenuation for the undesired  $TE_{0n}$  modes

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(where  $n \geq 2$ ) comprising a circular waveguide comprising a pair of semicircular waveguide sections having the same radius,

a first dielectric so disposed in one of said pair of semi-circular waveguide sections that the propagation therethrough of said undesired  $TE_{0n}$  modes may not be adversely affected; and

a second dielectric so disposed in the other semicircular waveguide section that the propagation of both of said  $TE_{01}$  and  $TE_{0n}$  modes therethrough may be affected by said second dielectric.

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9. A circular waveguide mode filter as set forth in claim 4 wherein

said first and second dielectrics are replaced by a first and second magnetic materials in said pair of semicircular waveguide sections, respectively.

10. A circular waveguide mode filter as set forth in claim 8, comprising a thin metallic slab positioned to partition said pair of circular waveguide sections, and a resistive material in contact with said thin metallic slab.

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UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 3,787,787

Dated January 22, 1974

Inventor(s) Sadakuni Shimada, et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 51 : "ilustrating" should be --illustrating--

Column 10, Claim 9, line 2, change "claim 4" to --claim 8--

Signed and sealed this 3rd day of December 1974.

(SEAL)  
Attest:

McCOY M. GIBSON JR.  
Attesting Officer

C. MARSHALL DANN  
Commissioner of Patents